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XXVII.—*Histological Researches on the Formation, Development, and Structure of the Vegetable Cell.* By Prof. H. Karsten*.

[Plates V., VI., VII.]

Historical Introduction.

Since the period when Malpighi, Grew, and Leeuwenhoek laid the foundations of vegetable anatomy, and Moldenhauer, Mirbel, Bernhardi, Treviranus, Rudolphi, Link, Meyen, Unger, Dumortier, Mohl, and others demonstrated the tissue of plants to be composed of distinct independent cells, the history of the development of the cell itself has formed an object of inquiry. As yet, however, the researches made on this question have led to no uniform and constant conclusions, as, indeed, from the very nature of the inquiry, might have been anticipated.

On the one hand, Mohl, in 1835, maintained the hypothesis of the multiplication of cells by fission of pre-existing cells, effected by means of septa commencing as folds from the sides of the cells and advancing until they met in the centre. On the other hand, Schleiden seized on the fact of the frequent presence of a nucleus, which Robert Brown had pointed out in cells where an active process of development was going forward, and employed it to construct a contrary doctrine of cell-production.

Schleiden regarded this nucleus as the basis and builder of the simple cell-wall that encloses it, by effecting a transformation of the mucilaginous substance around it into a gelatinous envelope, which subsequently becomes the membranous wall. Into the gelatinous vesicle so formed Schleiden supposed the external fluid to pass on one side, and to distend it, so that the mucous corpuscle is set free on one side, but adheres to the inner wall on the other—and that then a second layer is produced on its free surface, whereby the nucleus becomes involved in a duplicature of the wall, or remains free, and is at length mostly dissolved and lost to view.

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* Translated by Dr. Arlidge from a separate impression kindly communicated by the Author.

The majority of naturalists are now agreed that, in the vegetable kingdom, free cell-formation from a more or less completely organized nucleus of a mother cell takes place, but is of rarer occurrence than the production of cells by fission, according to the views of Mohl.

In opposition to this hypothesis of a twofold type of cell-formation, I sought, in 1843, in my dissertation 'De Cella vitali,' to establish the fact that the development of organic forms is subject to one single law, to the recognition of which the observation of the phenomena of development both of vegetable and animal tissues had led me, and of the truth of which I remain convinced now, after twenty years' study of this question, alike important both for physiology and anatomy.

Since that *brochure* is little known, and has been in some measure misunderstood, I will reproduce here those conclusions which relate to the question under notice:—

1. The formation of every cell within a living organism is original: the cell is not divided into two new individuals by longitudinal or by transverse septa, or by proliferation. 2. The evolution of a cell does not depend upon an antecedent formation of a solid nucleus. 3. In the first phase of its existence the cell resembles a small vesicle, very like a mere point. 4. In the organism the "cell of vegetation" does not exist in a simple form; for everywhere a secondary cell is present. Every elementary part of the organism (the cell is deemed elementary) consists of a system of endogenous cells; a member which is sometimes interpolated in this system of cells is the "cell of secretion." 5. In the secondary cell......a nucleus is found, which Schleiden called the formative cytoblast of the cell, but which I regard as a small tertiary cell retarded in its evolution. 6. In the interior of a cell one or several cells are developed with greater or less rapidity, evidently in the same manner. 7. An organism potentially consists of one such system of cells, *i. e.* a cell of reproduction; actually of aggregated series, every one of which may be a cell of reproduction; never of a simple cell*.

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* 1. Omnis cellæ formatio originaria est, intra vividum organismum; cella dissepimentis longitudinalibus et transversalibus aut proliferatione in duo nova individua non disjungitur.
2. Cellæ evolutio non pendet ab antecedente solidi nuclei formatione.
3. In primo vitæ suæ gradu cella parva, puncto simillima vesicula apparet.
4. In organismo non exstat *cella vegetationis* simplex; ubique enim secundaria cella adest. Quævis organismi pars elementaria (cella q. d. elementaria) ex endogenarum cellarum serie constat; mem-

By this work I hoped not only to convince histologists of the compound structure of the elementary organs of vegetable tissue, the youngest member of which is the nuclear corpuscle, but also to prove to physiologists the intimate affinity of all the different endogenous members of one and the same system of cells, as well as the mutual action which takes place between the constituent walls of the endogenous cells and their fluid and solid contents—a mutual action from which not only the most material changes of form of the original structureless cell-wall proceed, but also the multiform and peculiar chemical combinations of its organic material.

The existence of a secondary cell in the tissue-cells of the large class of Algæ was proved by Kützing in the same year with the appearance of my essay, probably without his having any knowledge of the latter; and in the following year Mohl announced this structure, as ascertained by me, to be common to all plant-cells.

One portion of my work therefore promised to be serviceable immediately after its appearance,—the composite structure of the elementary organs of plants being recognized by the most experienced of histologists. But with respect to the functions of the different elements of this microcosm, and their purpose, I had not the good fortune to obtain Mohl's acquiescence; for whilst I sought to establish a successive endogenous formation of cells within one another, and was convinced of the continuation of an assimilative process in their often thickened and stratified walls, that illustrious observer adopted an opposite theory, and assumed that the thin, still nitrogenous delicate membrane which, at a certain stage in the development of most tissue-cells of plants, forms a lining to an outer and ligneous cell—the same membrane which I regarded as an endogenous secondary cell, growing eventually ligneous itself—is the first in origin (in Schleiden's sense) around the nucleus, the primary membrane of the whole system of layers found in the fully developed tissue-cell. He moreover implied that this cell-membrane, which he called the "primordial layer," remains un-

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brum, quod interdum huic cellarum seriei interjicitur, est *secretionis cella*.

5. In secundaria cella....nucleus invenitur....quem Schleiden cellam formantem cytoblastum....vocavit, equidem vero parvam cellam tertiariam habeam, ab explicatione impeditam.
6. In interiore cellæ parte citius tardiusve vel una vel plures novæ cellæ plane eodem modo nascuntur.
7. Organismus potentia ex uno tali cellarum systemate, i. e. *reproductionis cella*,....actu e cellarum seriebus aggregatis (quarum unaquæque ipsa reproductionis cella esse potest), nunquam ex simplici cella constat.

changed until the cellulose membranes are deposited upon its outer and inner surfaces.

Again, Mohl, Schleiden, and their followers supposed that in this way a long-unaltered envelope is formed around the contents, which are kept in constant change by continual diffusion; whilst to me the phenomena of development appeared to indicate a simultaneous and continuous chemical alteration both of the membrane and contents of the cell.

Having illustrated in that essay the manifold phases of development of the membrane of the secondary cells, and fully described elsewhere (Abhandl. der Berl. Akad. 1847, p. 111; Botan. Zeitung, 1857, p. 314; Poggendorff's Annalen, 1860, No. 4) the various chemical metamorphoses of the outer and primary cell-membrane, consisting, at a certain stage of development, of cellulose—changes which have been more fully established by Wigand (Desorganisation der Pflanzenzelle, 1862)—I shall here endeavour again to prove that all cells of vegetable tissue, as far as observation has yet gone, originate as minute free vesicles within the fluid contents of previously existing cells, and attain their normal dimensions after undergoing many determinate chemical changes; and, moreover, that the involution of the parent cell to form septa, as far as is yet made out, though it may accompany its multiplication, does not originate or cause it.

Besides the tissue-cells which originate in the juices of the cell, either singly for the maintenance of the individual, or several together for the purpose of multiplication, there appear in the cell-fluid generations of cells, originating and disappearing in manifold sequence, which are recognized as the producers of the more composite organic compounds, and partly also as the cause of the variety in the form of the thickening layers of the originally structureless membrane of the tissue-cells to which they adhere.

That these non-nucleated vesicles (starch, chlorophyll, &c.), spoken of by me as secretion-cells, are actual cell structures, and not structureless corpuscles, is not merely a curious histological fact, as it was in a great measure regarded by the older anatomists, but one of great importance to the physiologist; for if an anatomist of note, speaking of the constant tendency of anatomy towards the investigation of the most minute conditions of organization, has asserted that physiology will subside into a subtle anatomy, experience will soon show, on the contrary, that physiology will rather rise in a subtle anatomy.

In the following pages the nature of the origin and of the growth of all the cells of the different tissues of the organism cannot, necessarily, be demonstrated; for with many of them this would be scarcely possible, by reason of the peculiar conditions of their development: with others I have performed this task; and respecting the origin of the rest, I have assumed it to be analogous.

Doubt has been thrown partly upon my observations, and partly upon the conclusions drawn from them. In order to complete the former by a detailed statement of the phenomena which most appeared to stand in opposition to my view, I will here especially demonstrate the free endogenous origin and growth of cork- and pollen-cells, and of the tissue-cells of the simple Algæ, which have chiefly been cited as evidence of cell-formation by constriction; and I shall then consider myself justified in assuming that the same law applies also to the origin and growth of other cells.

By the fuller elaboration and the solution of these questions, the conviction will be arrived at that the vesicular structure (which takes on at once the character of an active cell, and the properties of which are dependent on the peculiar relative composition of its formative materials) progresses in a course of development determined by continuous changes in the physical and chemical condition of its membrane and cell-contents, therein resembling the organism at large, in the effectual working of which it has its own part assigned to it.

By this means physiology will acquire the necessary basis for the right understanding both of the vegetative and animal functions of the organism, which it is now attempted to explain, in an equally one-sided and defective fashion, as the action of a few or individual physico-chemical forces governing the evolution of the cell.

§ I. *Development of Cork-cells.*

In *Cecropia.*—In *Philodendron*; in the cells of which they also develope manifold.—Porous, thickened cork-cells.—Restoration of their original spherical form by ammonia.—Absorption of their mother cells.—Growth of a cork-cell out of a cell into the neighbouring vessel.—Cork-cells in crystal-cells.—Cork-cells not developed in lacteal vessels and branched fibrous cells of the bark.—Cork-cells and callus-cells anatomically equivalent.

The origin of cork-cells within those of the epidermis and bark has hitherto been ascribed by the few anatomists who have expressed a definite opinion upon this subject to the sudden appearance of a partition dividing the mother cell into two parts. This opinion has arisen from the circumstance that the investigations upon which it is based were made upon the cork-formation of the bark, which does not present a favourable example, as in it the actual moment of the formation of new cells in the bark may easily be missed.

The statement given by me as to the mode of production of cork, in my investigation of *Cecropia peltata*, Linn. (Acta d. Akad. d. Naturf. xxiv. pt. 1. p. 86) has not been taken into consideration by my successors. In this plant, in the outermost lamina of a collenchymatic tissue covered by the epidermis, and at the commencement of the second period of vegetation, I observed the formation of some small cells, filled with colourless fluid, in contiguity with the chlorophyll-vesicles. These colourless cells develope themselves, in the peripheral cells of the lamina in question, into cork-cells simultaneously with the absorption of the chlorophyll, and in those on the central aspect into parenchyma-cells of the bark, in which cork-cells are subsequently formed in the same manner.

Less difficulty is experienced in the observation of the formation of cork-cells when this tissue is developed in the process of cicatrization after an injury to a stem, by which the normal functions have been suddenly arrested—a circumstance partially studied by Mohl in his memoir on the process of cicatrization in plants (Botanische Zeitung, 1849, sp. 641). Hitherto I have been most successful in following up the history of the development of cork-cells in all its stages in the commonly cultivated *Philodendron pertusum*, Kth.

If a stem of this plant be cut through at the middle of the internodes, and the lower extremity of the piece cut off be stuck in moist earth, as soon as the adventitious roots already formed in the bark begin to be developed, very similar but not quite identical alterations take place in the tissues contiguous to the two cut surfaces. The organic constituents dissolved in the evaporating nutritive fluid collect beneath the dried layer of cells which soon covers the fresh-cut surface on exposure to the atmosphere, and are partly assimilated by the cells of which the various tissues of the mature stem of *Philodendron* are composed, and partly coagulated and chemically altered in many ways within the cell-membrane by the air which penetrates into the wounded tissues.

On the end dried in the air the stratum of cells saturated with nutritive fluid, but completely desiccated, is considerably thicker than on the lower extremity, where it consists of one or a few layers of cells; the vascular bundles also dry to a greater extent inwards than even the cellular tissue, so that a dead portion of these afterwards projects into the living tissue, and appears as if the latter had grown over it.

Within the cells, rich in plasma, which lie next the withered layer, nuclear cells, containing nuclear corpuscles, make their appearance. These, however, do not acquire the size of the parent cells, but become displaced by two cells originating and growing with them in the juice of the cell, and either nucleated or non-nucleated according to the chemical constitution of the plasma, or are enclosed between these during their growth, and absorbed; at any rate, they disappear.

The two newly formed and very thin-walled cells subdivide within the cavity of the mother cell, and so completely occupy it, and are so intimately moulded to its walls, its pores, rings, and spiral windings that they can scarcely be distinguished from its membranes. In the same way, the septum, which owes its origin to the apposition of the two daughter cells within the parent cell, is of such great tenuity as to appear like a single lamella.

The same new formation proceeds in the cells of the cortical tissue next the epidermic layer; and in this region the newly formed tissue extends from the cut surface almost as deeply within the cell-tissue as the dead portion of the vascular bundles. These newly formed pairs of cells are always arranged, in the upper section exposed to the air, in a direction perpendicular to the adjoining dry and air-containing cell-tissue, and more or less indeed in the same peculiar manner as the cork-cells of the bark, forming uninterrupted rows with the successively produced young cells. These are united in the parenchyma in a plane parallel with the cut surface, and which, close to the epidermis and round the vascular bundles, is turned inwards. By this means the surfaces of the dead extremities of the vascular bundles projecting into the living parenchyma are invested by a sheath formed by a stratum of cell-series standing perpendicularly to their longitudinal axis.

This production of cork-cells is moreover found not only in the cells of the parenchyma, but also in the cells and vessels of the vascular bundles; so that even the latter become occupied by a layer of cork-cells, and the undisturbed tissue of the internode is separated by this intimately adherent layer of cork-cells from the withered tissue, and also protected from the immediate influence of the atmospheric air.

The cork-cells do not always arise in pairs, but in larger number sometimes in cells of greater length. In the elongated cells of bast and wood, as well as in the vessels, there are usually numerous cells, arranged in rows, beginning at the end towards the cut surface, filling up the long cells more or less completely. In the vessels, moreover, they still oftener give origin to an irregular tissue.

The enlargement of the cells filled with transparent fluid, produced together with the cell-nucleus, must take place with extraordinary rapidity in the vicinity of the cut surface, in the manner that may be directly observed in the tissue-cells of a species of *Œdogonium* which will hereafter be described. This may explain why Mohl and Sanio did not observe it, and why I only succeeded a few times in meeting with stages of development corresponding with that shown in Pl. V. fig. 8.

The presence of a lamina of cork of some thickness retards, on the one hand, the flow of nutritive juices and their concentration by evaporation, and, on the other, restricts the action of the atmosphere on the cells assimilating it; the newly generated cells then extend themselves more slowly, and even appear to remain in a half-evolved condition; at least, in the line of demarcation between the cork and the unchanged cells of the tissue, some of the latter are occasionally noticed to contain delicately walled cells and vesicles, which possess the chemical constitution of cork, and present all the intermediate stages to that of the completely developed periderm, as is shown in Pl. V. fig. 2 *x*, in the case of a thickened porous cell of the medullary sheath, and, in fig. 5, in that of a vessel.

The most recently developed peridermic cells behave like cellulose with a solution of iodine and chloride of zinc, but soon lose the property of becoming blue on the addition of iodine and corrosive reagents, which property they indeed do not possess in the first period of development. Probably cell-nuclei occur in all cork-cells during a certain stage of development; and their duration seems to depend on the quality of the nutritive fluid absorbed by the cell-tissue, and on the chemical composition of the plasma within the cells, as well as on the more or less immediate access of atmospheric air.

The first-formed cork-cells contiguous to the withered cell-layer mostly remain simple, whilst those subsequently produced contain a further generation of two or more new cells. In this manner such a cork-cell becomes occupied by a complete cell-tissue, the very delicate walls of which are in such close apposition that they leave no intercellular spaces between them, and cannot be recognized as consisting of a double membrane.

Some layers of these cork-cells in the immediate vicinity of the cut surface, soon after their evolution, acquire stratified thickenings of their secondary cells, which are penetrated by a few pore-canals.

On resolving the tissue containing the cork-cells into its separate cells, by boiling it with nitric acid and chlorate of potash, and on subjecting it to the action of ammonia, the cellulose walls of the parenchyma become more or less greatly swollen, or are entirely dissolved. In the latter case, the solution of ammonia also acts upon the coherent groups of cork-cells derived from the dissolved cells, and causes them to swell up, to assume a spherical form, and to part asunder (figs. 14 & 15). In this way the true nature of the apparently simple lamellæ which form the septa is placed beyond doubt.

The cork-cells which are found in the much-thickened fibrous cells of the bark, furnished with deep porous canals (Pl. V. figs. 1 & 19), exhibit with particular clearness the true impression of the cell-cavity which enclosed them (fig. 20). The same fact is also displayed in the cork-cells of the very thickened parenchyma-cells and spiral vessels (figs. 2, 3, & 4).

During the process of development of these endogenous cork-cells, the substance of the walls of the parent tissue-cells becomes entirely absorbed. And by means of this process of absorption the various component tissues of the stalk are eventually replaced by a completely homogeneous layer of cork, in which the outline of the original histological elements cannot be recognized, as Mohl has shown in his researches on the normal cicatrization of the stalk after the fall of the leaves and that of the points of its terminal shoots.

The dissolution of the walls of the tissue-cells filled with cork-cells commences with the external membrane of the primary cells, and terminates with the inmost layer of the secondary cells; so that the pores of the very thick porous cells of the medullary sheath acquire large dimensions shortly before their final disappearance.

In the case of spiral vessels filled with cork-cells, the spiral fibre is not unfrequently left; it then coils round the serially appressed cork-cells, and may be untwisted from them (fig. 3). This condition affords still more certain proof of the presence of these endogenous cells within spiral vessels, and also of the fact of their being free isolated cells which more or less completely fill the cavity.

Sometimes, however, specimens are met with which prove that the filling of a spiral vessel with cells has proceeded from the neighbouring tissue-cells, the endogenous cells produced in and entirely filling which have extended from them into the adjoining spiral vessel (fig. 4). Hence the supposition might be entertained that the incompletely developed cork-cells found in porous vessels and cells (figs. 2 & 5) have likewise not freely originated in them, but have grown into them from neighbouring cells. Nevertheless, by causing the vessels set free by boiling with nitric acid and chlorate of potash to rotate on their axes, we may positively ascertain that their contents are really perfectly isolated free cells.

The cases in which the intrusion of a cork-cell into a spiral vessel from an adjoining tissue-cell is observed are uncommon; and such are, without doubt, due to a coalescence of the woody cell with the vessel before the development of the periderm, as

I have repeatedly observed, for example, in the wood of *Cinchona.*

Among the large cells of the vertically elongated parenchyma of the stem of *Philodendron,* some scattered rounded cells are met with almost completely filled with a large crystalline mass of oxalate of lime. In these cells also, when occurring in a mass of cork-tissue, some young cells are seen to originate between the crystalline mass and the parent cell, which, after having acquired their full dimensions, have a cellulose composition, and ultimately become converted into cork. These cells so entirely surround the crystalline mass that it appears to be enclosed within an envelope of small irregularly shaped cork-cells intervening between it and the parent cell-wall (fig. 2 *k*).

Besides these kinds of cells, which all contribute to the cicatrization of the cut surface by the formation of cork, two other elementary organs are encountered in the tissue of *Philodendron;* in these no cell-development takes place, but they become absorbed within the layer of cork-cells. The first of such organs are the series of cells, united with fibres and filled with raphides, which are found dispersed in the parenchyma of the bark and of the medulla, and which in other Aroideæ contain a milky juice. The second kind are the branching fibrous cells found only in the cortical tissue. Both these structures are, in all probability, principally concerned in the process of secretion—an opinion which I expressed suppositively, in my 'Dissertation,' with regard to the thickened secondary membrane; I also specially mentioned the absorption of the fibrous cells of the bark, in my Memoirs on the Palms and on the China-barks (Die Vegetationsorgane der Palmen, 1847, p. 53, and Die med. Chinarinden Neu-Granada's, 1858).

These fibrous cortical cells of the *Philodendron* have a remarkably ramified form, giving off from each side of the upper and lower extremities of the parallelopipedal and horizontally extended cells two very long and thin branches, which lie free in the comparatively wide intercellular spaces, and end in pointed closed extremities. These long branches, standing out at right angles from the cell, are not produced until after this has attained its full size; and soon after the outgrowth of these processes the entire cell-wall proceeds to increase in thickness. It can indeed be distinctly made out that these cortical cells, as well as the lacteal vessels, here occupied by raphides, originate from cells, and not from intercellular spaces lined with cell-material.

In my paper on tannic acid (Monatsbericht der Berl. Akad. der Wissenschaften; 1857) I described the lacteal vessels of *Colocasia, Dieffenbachia,* and other Aroideæ through which a fluid containing tannic acid is diffused. These lacteal vessels resemble the ramified fibrous cells of the bark, in sending off branches into the intercellular spaces, the membranes of which, from their extreme tenuity, may be readily overlooked, and thus give rise to the inference that the lacteal fluid circulates within the intercellular spaces themselves. I believe I have proved in that memoir that the lacteal vessels do actually possess walls of their own; they are therefore, with reference to their mode of origin, analogous organs to the fibrous cells of the bark.

The processes which go on in the formation of the so-called *callus* on the lower part inserted into moist earth are precisely similar to this formation of periderm; and this was particularly the case in cuttings of *Philodendron* when these were terminal shoots, and had continued to develope themselves after their separation from the lower part of the stem.

Under these circumstances also, a layer of cork is first produced on the cut surface (which, owing to its being implanted in the moist earth, scarcely undergoes any desiccation), to protect the living tissues from the access of air. However, the cork-lamina does not acquire the same proportion as in the process of cicatrization in the air, nor does it penetrate so deeply within the plant-tissue near the epidermis and vascular bundles; and after the peridermic layer has attained a certain thickness, the cells formed deeper within the tissue are not cork-cells, but, like the cambium-cells of the apex of the axis, become converted into the most various histological elements.

Two cell-nuclei are frequently met with in one mother cell, each containing either two nucleolar corpuscles or two vesicles of a larger size and having each two nuclear cells, whilst no cell-nucleus belonging to the cell-system of the mother cell is contemporaneous with them.

Crüger, who first fully described (Botanische Zeitung, 1860, p. 369) the changes in the cell-tissue during the formation of callus, supposed that no new formation takes place in the cut vessels. This, however, is an error ascribable without doubt to the great tenuity of the walls of the endogenous cells, the appearance of which is a counterpart of what has been already described and figured (Pl. V. figs. 3–5), except that these cells are still more hyaline and transparent, inasmuch as they are defended from the contact of the air, and consequently not rendered suberous (*verkorkt*).

I have found the vessels contiguous to the callus filled with new cells, not only in endogenous but also in exogenous plants —for example, besides *Philodendron*, in *Zingiber*, *Dracæna*, *Zamia*, *Cycas*, *Ficus*, *Gesneria*, &c. In all cases the fully developed vessels have a much greater tendency to generate new cells in their interior than the ligneous cells themselves, and this even without any wounding of the vessels. I removed a ring of bark from a twig of *Salix babylonica,* and found, in the following year, all the vessels of the peripheral lamina of the wood entirely filled with cells, whilst the woody cells, on the contrary, remained unaltered. The cells thus formed in the interior of vessels may, under certain circumstances, be transformed into new vascular cells, after the thickened wall of the parent vessel has been absorbed, and may contribute to the lengthening of the original vessel—a case which I have described and figured, in my researches on the organs of vegetation of the Palms, with regard to *Lycopodium Springii* (pp. 120 & 163, pl. 9. fig. 15), the vascular bundle alone having been developed into a root-fibre.

By the maceration in solution of potash of the cells which make their appearance in the vessels during the formation of callus, it may also be demonstrated that they are not produced by constriction, but as free vesicles in the fluid contents of the cells and vessels, although the observation of the moment of their production presents exactly the same difficulties here as in the case of the suberous tissue.

§ II. *On Cell-formation in* Œdogonium.

New joint-cells by evolution of endogenous cells.—Absorption of the secretions of the mother cell, with contemporary formation in the daughter cells.—Absorption of the nuclear cell.—Development and growth of the nuclear cell.—Cellular contents of the developed joint-cells.—Downward-prolonged annular folds of the primary cell-wall.—Bary's globules of decomposition contain animal parasites.

The peculiar behaviour of the mother cell, in the several species of the genus *Œdogonium,* during the formation of daughter cells, has been most fully elucidated by Bary (Schriften der Senkenberg'schen Gesellschaft, Band i. 1854–55). From his investigations we know that, in the course of elongation of a joint-cell, the primary cell-wall forms at its upper part an ingrowing annular fold, and that this fold, after the membranous envelope covering the mother cells is torn through, suddenly extrudes itself, and thus causes a considerable elongation of the joint-cell.

The internal structure of the *Œdogonium*-cells and the mode of multiplication of the joint-cells have, however, not yet been ascertained. The latter is, as usual, represented to be a consequence of the formation of septa by constriction of the walls; and, according to Bary, the septum is formed in the suddenly extended cell within a colourless layer which divides the green mass of contents into two parts, and not until this layer has issued from the lower sheath-like portion of the circularly torn membranous wall, in consequence of the gradual expansion of the inferior mass of the cell-contents. Bary regards the lower of the two new and simultaneously produced cells as the parent of the upper.

The real process of cell-multiplication does not agree with this description. The transverse cell-wall does not originate only outside the enveloping membranous sheath, in accordance with the prevailing opinion, by the inward growth, from the surrounding wall of the elongated mother cell, of a fold-like or lamelliform horizontal septum ultimately meeting at the centre, but, on the contrary, it is present and complete before the rupture of the membranous wall and the occurrence of the abrupt elongation of the mother cell.

The thickening, and not the formation of the transverse septum, follows after the changes described by Bary have taken place in the mother cell when this escapes from the membranous enveloping sheath, which until then encloses that portion of the joint-cell in which the transverse septum arises, by the development of daughter cells, in precisely the same way as the formation of cork-cells in *Philodendron pertusum* has already been described.

The existence of the transverse septum in the joint-cells which are not yet elongated, and indeed in those in the upper end of which the fold of the mother cell is already produced, is particularly easy of demonstration in the species of the genus *Œdogonium,* as Hartig and others have indeed actually witnessed; but it is not so with respect to the mode of origin of the septum. The great quantity of chlorophyll- and starch-corpuscles which cover the inner surface of the cell-walls of these plants, when in vigorous growth, renders it impossible to make out with any certainty the development of new cells within these joint-cells.

In my researches I employed plants of *Œdogonium grande* which had been raised from spores in pure water, and many of whose cells were scantily occupied by chlorophyll, so that the changes which took place in the other contents could be more clearly examined.

In such plants it is possible to make out the true mode of formation of the septum, which is thus effected:—two of the many non-nucleated hyaline cells which occupy the interior of the joint-cell acquire a greater size (Pl. V. figs. 21, 26, & 28), and by their growth press the others to one side against the wall of the mother cell (which is coated with chlorophyll, starch, &c.), and eventually come into contact and by their mutual apposition form the septum, often obliquely placed at first, and completely fill up the cavity of the mother cell (figs. 27 & 29).

This process occupies some few minutes; and in order to observe it the eye must be fixed upon some one such cell containing but little chlorophyll, and in which the fold of the wall is fully formed, though a septum be as yet not present in it.

After the septum has attained the characters of a complete disk dividing the cell-cavity, an act of growth, or at least an expansion of the cell-wall, still goes on, whereby the rather obliquely placed septum acquires a horizontal direction, and a certain amount of pressure is at the same time exerted upon the cell-wall, which forces apart or extends the fold (above which the enveloping membrane is torn through), and thus enlarges by about one-third of its length the mother cell of the two newly developed cells (figs. 22 & 23).

Contemporaneously with this sudden evolution of the mother cell, the two endogenous cells undergo expansion. When both these cells are not equally enlarged, it is, as a rule, the upper one (usually the smaller of the two) which at first expands comparatively more strongly, and at the same time downwards towards the new septum, whilst the chlorophyll- and starch-vesicles, compressed against the walls of the mother cell, do not at first undergo very much displacement. This is the reason why, at the first moment after the extension of the mother cell, the new septum is usually found free from secretory vesicles, and only bounded by a transparent watery fluid (Bary's colourless layer), as happens also with the inferior extremity of the lower of the two daughter cells.

This primary and abruptly accomplished enlargement of the endogenous cells, after the laceration of the enveloping membrane, is, like that of the mother cell itself, only a mechanical act,—not a process of growth, but merely the extension of the cell-wall already enlarged by assimilation. The secretion-corpuscles, however, gradually distribute themselves equally over the whole surface—except that, quite at the upper end, at the summit of the mother cell, a compact group of these secretion-corpuscles remains, even in cells otherwise almost destitute of such contents, whilst the lower extremities of the two young daughter cells usually continue longest free from these substances, and appear colourless.

Nevertheless, this distribution of the secretion-material is not so rigorously subjected to the rule just mentioned as not to admit of exceptions.

These relations are, however, it appears to me, worthy of notice, because they may furnish data for arriving at conclusions respecting the place of formation of the secretory material, the direction of the cell-growth, and therefore the direction or course of the nutritive matters distributed in the series of cells.

It would appear that those materials which are subservient to the growth of the young cell-wall pass from the lower to the upper portions of the plant, whilst chlorophyll is produced from compounds which diffuse themselves from the upper into the lower parts of the plant.

During the first period, which ensues upon the unfolding of the annular fold and the extension of the cells, the upper young joint-cell usually remains more or less unchanged; the lower one, on the contrary, continues to enlarge, whereby the new and still delicate transverse septum becomes pressed upwards, until it at length projects from the opening in the lacerated membranous sheath, and then it proceeds to increase in thickness. (Pl. V. figs. 23, 24.)

Bary asserts that he distinctly made out that the septum is produced by a gradual constriction and secretion of the primordial layer, in various species of *Œdogonium,* after the protrusion of the clear lamina from the membranous sheath. In the treatise quoted (at p. 42) he says:—"In any case, the septum is not simultaneously formed in its entire surface; on the addition of a solution of chloride of zinc and iodine, the contracted primordial layer is sometimes distinctly seen to pass through the middle of an incompletely closed dissepiment."

That this phenomenon, which I have figured in a *Spirogyra* (Pl. VII. fig. 67), and to which I shall hereafter revert in connexion with *Cladophora,* furnishes no sufficient proof of the production of the dissepiment by constriction, will be shown when I come to speak of the latter genus.

Of the formation of a fold in the membrane of the mother cell, after the two daughter cells (figs. 21, 26, 28) have become mutually pressed together so as to form a complete septum (figs. 22, 27, 29), and of an eventual inward extension of this fold betwixt the lamellæ of the septum, which are thus again separated, I have no knowledge; but the more distinct appearance of the long-previously existing septum can, in my opinion, be much more readily accounted for by the gradual thickening that progresses in it from its circumference. That this thickening of the septum always follows after its emergence from the enveloping sheath is in all probability to be attributed to the changes in the nature and operation of the nutritive matters derived from without, now only through the walls of one assimilating and secreting system of cells.

In the mean while, the upper of the twin cells also begins to grow vigorously, until at last it equals the lower one in length. Nevertheless it not unfrequently remains somewhat shorter, which is the cause of the irregularity seen in the structure of *Œdogonium.*

Nägeli urges, in opposition to the notion of the formation of free cells in the fluid contents of a cell laden with various solid matters, that changes must have been observable in the solid contents adhering to the wall of the mother cells, should these become dissolved in the mother cell and afterwards organized anew in the daughter cells.

Well founded as is this supposition of Nägeli's as to the metamorphosis, the notion that such a metamorphosis does not take place is equally unfounded. Indeed, in my essay 'De Cella vitali' (1843, p. 71), and elsewhere, I have maintained the occurrence of those conditions subsequently called in question by Nägeli, asserting, as a result of my observations, that the secretion-material contained within the mother cell serves as nutritive matter for the ensuing generation. A conviction of the entire correctness of this statement, and of its high importance for the right understanding of cell-life, may be most readily attained by the examination of the species of *Œdogonium*, which, on account of their remarkable tenacity of life (in which they almost equal *Conferva glomerata*), are particularly well adapted for being observed continuously under the microscope during the successive stages of their process of growth.

Indeed the entire cell-contents of the joint-cell, which has been recently divided in the manner described into two portions, are now found interposed between the outer surface of the two daughter cells and the inner aspect of the wall of the mother cell. The large, thin-walled, non-nucleated cells (vesicles), filled with transparent fluid, existing at the time of the growth of the daughter cells, are at this period no longer present; indeed they disappear during the first stage of development of the young daughter cells, to which they probably serve as nutritive matter. On the contrary, the chlorophyll and the usually large starch-granules met with in the different species of *Œdogonium*, in variable quantity according to external vital conditions, are rather rapidly dissolved during the growth and the thickening of the membranous walls of the young joint-cells, in order to supply nutritive material for the process of assimilation of the cell-walls as well as for the new generation of cells and of secretion-vesicles in process of formation within the two daughter cells. This dissolution of the starch-corpuscles is completed in about twenty-four hours.

The chlorophyll first undergoes this process of absorption, and afterwards the large amylaceous corpuscles; and then they progressively reappear, but in the opposite order, in the interior of the newly formed joint-cells. In the first instance, small starch-corpuscles make their appearance, then the chlorophyll-vesicles, and, lastly, those large hyaline vesicles which, in the normally developed and well-nourished cell, are for the most part not perceptible externally, and which originate by the growth of small yellowish-coloured vesicles, very similar to those of chlorophyll in their earliest stage. In many cases also it may be distinctly seen that a starch-corpuscle occupies the position of a nucleus within mature chlorophyll-vesicles.

Bary's idea that chlorophyll occurs in the external layer, and starch more in the interior of the joint-cell, will not, therefore, hold good. Indeed, in my researches on *Vaucheria* (Botan. Zeitung, 1852), I showed that in that plant the starch was usually to be found towards the exterior of the cells that contained chlorophyll. The same obtains in *Œdogonium,* in those cells in which new joint-cells have originated. The large, much-thickened starch-corpuscles, when chlorophyll is not present with them, are met with external to the cells which contain chlorophyll as well as delicately walled starch-vesicles. The explanation of this relation is to be found in the successive development of new endogenous cells within the joint-cell of the *Œdogonium.*

As the phases of development of neighbouring joint-cells of *Œdogonium* differ very much from each other, so also do the joint-cells often present very different conditions in regard to the distribution of the secretory materials contained within them.

The true nature of the functions of the nuclear cell (nucleus) in relation to cell-formation in general, as well as to the multiplication of cells, in the case of *Œdogonium,* has not been rightly understood. A cell-nucleus is frequently absent from the cells of *Œdogonium* during the formation of new cells—probably, indeed, more frequently absent than present; and without doubt its existence, or rather its form, is dependent on the conditions of nutrition and on the chemical composition of the plasma. Besides, where the nucleus is present, it can be shown that the origin of new cells, and still more the formation of a septum, is quite independent of it.

In those cells wherein a nucleus of the ordinary form exists at the time of the formation of new cells, it is found to lie often on the wall of the mother cell (fig. 28), often in the median line, sometimes at its centre, and at others nearer to one end; and, in the course of the growth of the daughter cells, which do not originate in contiguity with it, it becomes thrust to one side along with the other contents, and pressed against the inner wall of the mother cell. In this position it immediately begins to undergo absorption—a process which seems to be frequently preceded by a swelling-up of the nucleus. Mostly this act of absorption is speedily completed; and then only does a nucleus make its appearance in each of the two new joint-cells, hitherto destitute of any solid contents, and prior to the origin of any of the other varieties of secretion-vesicles (fig. 29).

In "resting" vegetative cells, *i. e.* in those which for a long time continue apparently unchanged, and which present no new formation of cells for the purpose of multiplication (neither vegetation- nor reproductive cells), there nevertheless occurs a continuous, though a very tardy, regeneration of the cells themselves.

Whilst the external primary cell-membranes are being dissolved, and replaced by the thickening membranes of the secondary cells, nuclear cells, long persistent in an embryonic condition, increase in size and assume the functions of secondary cells. The secretory materials contained in these (consequently exterior to the nuclear cell) are dissolved during this development of the nucleus, and within the nuclear cell, which has reached the dimensions of the mother cell, other similar secretory vesicles become developed.

In consequence of this development of the nuclear cells, secretion-vesicles are found not only on the outside of the two daughter cells, but also of the secondary cells, of the *Œdogonium* joint-cells at certain stages of development. These secretion-cells are usually starch-globules; for the chlorophyll was the first displaced and lost. (Pl. VII. fig. 63, as seen after the action of a weak solution of glycerine.)

In many cells a weak aqueous solution of iodine shows the presence of starch in solution betwixt the inner membranes of the cell. Mohl mentions this circumstance, and describes this, together with other allied structures, as a mucilaginous deposit around the primordial layer coloured blue by iodine (Botanische Zeitung, 1855, p. 732).

Before the application of the iodine, this layer has the appearance of a turbid solution of gum or mucus, but afterwards forms a clear transparent fluid: it therefore behaves like finely divided starch.

The two newly formed joint-cells, after the production of the septum by their apposition, cannot again be separated by the agency of endosmotic media, nor do they become detached thereby from the enclosing secondary cells of the mother cell.

If such cells are allowed to remain in saline or acid solutions, or in glycerine, &c., the membrane of the secondary cells enclosing the new cells and other contents loosens itself from the primary cell of the joint that is undergoing fission, and collects into a mass along with the whole of the contents in the interior of the cell: in this condition it shows no cellulose reaction.

It is not until after the further advance of the absorption of the secretory matters which occur outside the young joint-cells, after the thickening of their walls and of those of their mother cell has commenced, coincidently with the more distinct protrusion of the dissepiment, that the application of solution of chloride of zinc and iodine produces a blue coloration of the external membranes of the new joint-cells and of their now likewise thickened and closely embracing mother cell; and this happens contemporaneously with the detachment of a secondary cell, which up to this period could not be isolated.

The difficulty, or perhaps, at present, more correctly speaking, the impossibility, of effecting, by the agency of endosmosis, the separation of the closely approximated membranes of the two endogenous cells from their mother cell (the secondary membrane of the joint-cell), or, before the thickening of their walls, from the secondary cells within them, is owing in part to the nature of the intercellular substance, and in part to their very similar chemical and physical (diosmotic) properties.

The similarity or identity of these membranes is so great, indeed, that it is extremely difficult to determine whether the young cells consist of a single or double cell-wall, and whether the enveloping secondary membrane of the mother cell is still present or has been destroyed. It is moreover somewhat difficult to make out with certainty the presence of the large vesicles filled with colourless fluid amid the corpuscles of chlorophyll and starch within the cavity of the cell.

In many species of the genus *Spirogyra*, and still more easily in *Cladophora glomerata*, we may ascertain, by cutting through their joint-cells under water, or by the action of different reagents, that these cells are filled with a delicately walled cellular tissue. And we may sometimes be so fortunate as to witness the complete extrusion of the new joint-cells (themselves also occupied by cellular contents) from the mother cell before their membranes are thickened.

In *Œdogonium*, the joint-cells of which acquire cellular contents only after they have attained their full size, and simultaneously with the commencement of the thickening of their walls, these are no longer protruded from their mother cell; and in their younger phases (in which, as they then only exhibit fluid contents, they cannot be distinguished from the large neighbouring secretion-cells) they are furnished with walls as delicate as those of the latter, and are immediately dissolved by contact with water. Indeed it is only when sections of such plants are made in a weak solution of gum-arabic, instead of water, that we can succeed in observing for any length of time the very delicately walled, easily overlooked, endogenous, non-nucleated cells emerging from their parent cell; and even then it is impossible, for reasons already stated, to distinguish whether these are only transitory secretion-cells or the early stages of development of new joint-cells.

It has been satisfactorily shown by former observers, and especially by Bary, that the thickened membranes of *Œdogonium*, and particularly the extensile annular fold, behave with reagents like cellulose. To these statements I can add that this annular fold consists solely of cellulose, even before its extrusion.

In the ordinary course of development of *Œdogonium*, this investigation is difficult, on account of the instantaneous rupture of the membranous envelope, and the sudden extension of the fully developed fold, on the application of the reagents necessary for these experiments.

In specimens placed in the direct rays of the sun, in order to excite them to more rapid development, but which had to support a temperature too high for their normal vegetative activity (namely, 35° Réaumur), the membranes of the secondary cells acquired considerable thickness whilst yet enclosed within the primary cells, which still exhibit their annular folds, as shown in fig. 25.

In these cells it could be seen distinctly that the annular constriction consists entirely of cellulose—that is to say, that it exhibits the cellulose reaction with solution of iodine and chloride of zinc—as the annular fold did not extend itself even on the application of that reagent.

The contents of these unusually thickened cells consisted of comparatively large hyaline non-nucleated cells, with pale-green starch- and chlorophyll-corpuscles and reddish-coloured oil-drops (?) thinly scattered between them. A large accumulation of chlorophyll was observed in the upper end of the cell.

These *Œdogonia* soon became quite colourless; the large transparent vesicles disappeared; and only the oil-particles, and especially the decolorized starch-corpuscles, remained undissolved and unchanged in the dead membranes for any considerable time; even the annular fold vanished by solution, though the rest of the same cell-wall continued unaltered.

Similar individuals, with greatly thickened secondary cells, I have observed now and then among normally developed forms. In these also the annular fold had not expanded, though the investing envelope, consisting of a double membrane (probably the cuticle and the remainder of the membrane of a primitive mother cell), was annularly torn through above it. Indeed, in a few days, the fold was dissolved in the water, and its former existence evidenced only by an empty space. In these cells two young joint-cells had been formed—one, the larger, occupying the space below the annular fold, the other the small space of the mother cell above that fold. Both these young cells were filled with secretion-vesicles; and occasionally I succeeded, by adding a thin endosmotic medium, in separating the two, not only from the wall of the mother cell, but also from one another; they contained all the chlorophyll present; and by the plan pursued the two endogenous membranes of the mother cell also became somewhat detached from each other.

In other joint-cells of the same individual, two young cells, alike in dimensions and position to those above described, were also present; but these could not be separated, by a similar proceeding, from one another, nor could the two endogenous membranes of the parent joint-cell be detached, or the existence of two superimposed cells be any longer distinguished with certainty. By the endosmotic current, however, a delicate daughter cell was detached from the thickened membrane of the new joint-cells, which was then recognized as the true immediate envelope of the endogenous secretory material.

These joint-cells therefore constituted a somewhat more advanced phase of development, as indicated also by the incipient thickening of their primary membrane.

As, in the cells just described, secretory matters occur not within the now rather thickened primary cells, but, as usual, only within the secondary cells, it might seem doubtful whether the outer membrane which was in course of thickening does actually represent an independently existing cell, or whether it might not probably be only an external thickened layer, transformed into cellulose, of the original cell-membrane, of which the remaining portion constitutes the inner, delicate, and probably still nitrogenous membrane.

In opposition to this view, which is by no means destitute of probability, and would give countenance to Mohl's theory that the inner secondary cell is of the nature of a primordial vesicle, several conclusive facts may be adduced. In the first place, it may be assumed, from the conditions of development above described (p. 282) and represented in Pl. VII. fig. 63, after treatment with glycerine, that here also the primary cell originally, or before the commencement of the thickening of its walls, contained secretory materials, then perhaps only in a fluid state, although these, at the time of observation, occurred within the secondary cell. A still more valid argument, though certainly resting only on analogy, is furnished by another developmental phase observed by me, wherein the primary cell-wall, instead of growing inwards so as to form the well-known annular fold, in the normal manner, produced (as seen in fig. 49) a fold extending downwards between the cell-walls of the mother and daughter cells.

This interesting condition was met with in several joint-cells of filaments the other cells of which exhibited the normal annular folds; and I only noticed it with clearness after the action of solution of iodine and chloride of zinc upon the plant had tinted the deeply penetrating fold of the cell of a dark blue colour. By this means it was seen to extend very gradually and to outstretch itself, until it had fully emerged from the membranous sheath and became no longer distinguishable from a cell which had suddenly extended itself in the usual manner. The secondary cell was contracted around its contents, as is exhibited in Pl.VII. fig. 49; but sometimes also the chlorophyll and amylaceous contents expanded themselves and filled the whole of the lower space of the cell as far as the margin of the enveloping sheath.

This phenomenon I once observed taking place in several individuals of *Œdogonium grande* with great uniformity, and, as the evolution took place very slowly, with great certainty; but since then I have looked for similar examples in vain, and can therefore, much to my regret, contribute nothing further respecting the conditions under which this interesting act of fold-construction takes place.

Nevertheless it furnishes a fresh proof against the view spoken of—namely, that the cellulose membrane is the external thickening layer (or, as Mohl's school would represent it, excretory layer) of the secondary cell,—and can only be explained by the developmental faculty of the independently assimilating cell-wall.

Moreover the opinion that the normal annular fold is simply an excretion from the primordial sac is completely hypothetical. There is nothing to show that the secondary cell possesses in the portion contiguous to the ring any other or stronger powers of vegetation than in any other portions.

Besides the well-known and frequently described development of spores and gonidia, I also observed other organs, the functions of which are still unknown to me, but which, on account of their aberrant and strange developmental phenomena, certainly merit more general attention; for which reason I do not think I shall be accused of precipitancy for publishing here the little that I have observed respecting them.

Bary indeed appears to have met with something similar; for he has described and figured (Senckenberg Transactions, vol. i.) certain "globules of decomposition" (Zersetzungskugeln), which were produced from the joint-cells of dying specimens of *Œdogonium capillare, Œ. acrosporum,* and *Œ. echinospermum.* Bary saw the aggregated mass of contents form into a globule, and escape from longitudinal rents in a cell, commencing in the still unthickened and soft membrane of the recently extended annular fold. He more rarely noticed them escaping through the old and firm cell-membrane.

I have represented in Plate VII. the structures observed by myself, and which correspond in character with these globules of Bary. The phenomenon occurred in *Œdogonium grande*; the entire contents coalesced into a ball-like mass, which was protruded through a circular aperture in the thick-walled joint-cell, and formed on the outside a spore-like globule (Pl. VII. fig. 50). Alongside the opening there was a small disk, the size of the aperture, mostly adherent to one side of it, and which, without doubt, had originally closed it before being thrust out by the emerging cell-contents (fig. 50 *d*). The extruded, globular, spore-like corpuscle consisted of several nested cells, the two outer membranes of which frequently contained a single layer of small starch-vesicles, whilst the third was filled with chlorophyll and starch, and the fourth was occupied by reddish-brown vesicles.

The globular corpuscle was enveloped within a delicate transparent cell as in a sac, which was fixed by its lower and somewhat elongated extremity to the inner wall of the joint-cell near the circular aperture. Solution of iodine and chloride of zinc gave a beautiful violet-blue tint both to the saccular envelope and to the membrane of the globule. Bary did not remark this cellulose reaction of the enveloping sac; and in fact it is difficult to produce the coloration in the older globules which have been longer extruded from the mother cell. Yet, even under these circumstances, the true membranes of the globule are readily coloured blue. At a later phase of their development the starch-corpuscles vanish, and their walls become thickened and reticulate, or slightly porous (fig. 52).

The globule enclosed within the sac exhibits a mucilaginous peduncular body at its base, which is adherent, together with the lower end of the envelope, to the inside of the joint-cell. It appeared to me to be an inner envelope, which, however, is not so extended at this lower extremity as the outer one. The stem-like prolongation is also coloured blue by the same reagents.

Bary considers the saccular envelope to be a young membrane formed, probably at the time of extrusion, around the primordial sac, and continuous with the innermost layer of the emptied joint-cell. Consequently the outer membrane of the globule, or the delicate covering which in all probability serves as a lining to the sac and is prolonged into its pedicle, would be the secondary cell of the joint-cell.

For my own part, I have not witnessed the first act of coalescence of the cell-contents, but only the formation of such globules after they have begun to extrude from the circular aperture, and therefore have no knowledge of the origin of the different component membranes.

Many of the globules enclosed within the sac, although containing no starch, had somewhat stronger walls, not reticulate, but uniformly thickened. The chlorophyll- and starch-corpuscles enclosed within the third cell of the interior were present in smaller quantity; but, on the other hand, the mass of reddish-brown vesicles and granular mucilage in the fourth of those cells had increased, apparently at the cost of the secretory matters, especially of the chlorophyll, of the next adjoining external cell; this substance was in other instances entirely absorbed, and only the starch, in reduced quantity, left.

The red mass which occurs in the centre of the globule is usually at first not distinguishable through the chlorophyll, and probably is often altogether wanting, being only an accidental constituent, as in fact the future development tends to prove. Bary also describes the globules observed by him as brown, and as at length becoming of a dingy carmine-red colour.

I am unable to offer any interpretation of the purpose of this structure in plants. On account of the peculiar act of extrusion from the mother cell by means of the little lid which is always present, I am disposed to look upon the process as an independent and normal act of development, which, however, I have not been able to trace. On the other hand, I have noticed a very remarkable abnormal phenomenon in certain globules, the fourth internal cell of which was filled with red matter, which had more or less completely supplanted its vegetable secretory material. I have frequently seen such globules, whilst still enclosed within the sac and fixed to the joint-cell of the *Œdogonium,* become slightly distended outwards at a particular point on one side, and an opening form at a corresponding point in the thickened outer envelope of the globule, as well as in the closely adherent membrane of the sac, to give a passage to the enclosed red mass. The body which escaped through this aperture was smooth and amœbiform, and forthwith assumed a spherical figure, enveloped by a colourless somewhat granular coat, from which long ciliary processes proceeded; these were not stiff, but moveable and capable of shortening or lengthening themselves. The globular body, apparently making use of these moveable ciliary processes as organs of adhesion, rolled slowly about in various directions. Fig. 53 shows a body of this kind, magnified 700 diameters.

In general, two or three such bodies emerged in succession from the opening in the globule, and I have often observed them moving, in the manner above described, for hours afterwards. The sac, with the thick adherent membrane of the globule, either remained altogether empty, or some starch and the second inner cell-membrane continued visible. The small orifice through which the little amœba-like beings had escaped was only indistinctly perceptible. On three occasions I saw two of these globular ciliated bodies come into contact (fig. 54), adhere to each other, coalesce at the point of contact, and form a single motionless body. At the same time the whole of the cilia on the free surface very rapidly shortened, leaving the periphery completely smooth, whilst the granular colourless membrane became transparent, and constituted a structureless and rather thick envelope around the two coalesced bodies, which had now become completely united into a single, rather irregular, oblong body.

After a time this structure became flattened on the under surface; the red granular contents (of whose origin from two distinct masses no trace could any longer be discerned) now again underwent division into two portions, which were coated externally with red vesicles resembling oil-drops. Subsequently, within each of these segments, two globules separated, and in the place of these, again, numerous smaller ones made their appearance, a complete process of segmentation taking place, such as occurs in ova after impregnation. In consequence of this continued development of endogenous cell-generations, the object of which is doubtless the production of higher organic compounds, the thick-walled envelope, which is constantly undergoing certain changes of form, becomes now filled with a great number of small vesicles, which shimmer through the external red layer, consisting apparently of oil-drops, which lie immediately contiguous to the colourless membrane (Pl. VII. fig. 55). In the course of two days there is a distinct constriction of one half of the contents into several portions, as in the formation of an annulose animal (fig. 56).

The further development of the larva beyond this stage has mostly failed in my hands: in only one instance did it proceed to the third day; and even in this the animal escaped from the sac before its full form was visible (probably owing to the pressure of the glass cover, in consequence of the evaporation of the water around the object), in the shape and manner represented in fig. 57.

Unfortunately this phase of development is still so incomplete that it is not possible to determine accurately what animal it was. I am disposed to regard it as one of the Rotifera, of the genus *Rattalus*, specimens of which were abundant around. Nevertheless the above marvellous metamorphosis, followed out as it was for some time by myself, claims the attention of zoologists. I have to add to the foregoing fact, that a reddish-yellow-coloured *Amœba* is to be found living within the joint-cells of *Œdogonium* whilst still filled with chlorophyll, although more or less diseased, and that this being seems capable of penetrating from one cell to another. As to any connexion between this *Amœba* and that which emerges from an apparent spore-capsule, and as to the nature and object of the ulterior conjugation and metamorphosis of the globules, I will not now hazard an hypothesis. The well-known large eggs of the Rotifera and Crustacea cannot be enclosed within these developmental structures. Lastly, I have made no researches respecting the construction of the lid-like covers of the apertures, which would still be particularly deserving of notice even if the capsule protruded from the joint-cell were found to be nothing more than a diseased product induced by the operation of the parasitic animal germ.

These researches were made in June and in the beginning of July; and I have been unable to verify them at a later period of the year.

[To be continued.]

XXVIII.—*Notes on the Byblus-Rush and the Byblus-Bok.*

By John Hogg, M.A., F.R.S., F.L.S. &c.

In a paper "On Vessels made of the *Papyrus*," which I communicated to the 'Magazine of Natural History' in 1829 (vol. ii. p. 324, &c.), I gave a sketch (fig. 88) of an ancient vessel used on the Nile in Egypt, taken from the famous Mosaic pavement discovered at Palestrina (Præneste), and which is constructed with a high and *long prow*. A kind of boat used on the large Lake Nyanza, in Equatorial Africa, is shown in Capt. Speke's 'Journal,' p. 391, as having a *prow* somewhat *similar* in length, and which he describes as "standing out like the neck of a syphon or swan."

This coincidence, then, is not unworthy of notice, as showing that, in all probability, the Nyanza boat retains the early form of that very ancient Nile vessel. Capt. Speke does not say of what materials the boat is composed, and whether the *Byblus-rush*, now abundant in that lake-district of Africa, is ever used in "filling up the joints on the inside," or for forming the ordinary "sails," as it was in the time of Herodotus (Euterpe, cap. 96).

The *Byblus-rush* (*βύβλος* of Herodotus, or the *Papyrus antiquorum* of Sprengel) was once so common on the banks of the Nile that Ovid assigned the epithet *Papyrifer* to that holy river. Nor was the plant itself esteemed *less holy*, inasmuch as it was used by the Egyptian priests for the ornamentation of their statues and temples, and for a frequent model of columns, and as a representative in the ancient hieroglyphics. But of late